Branching ratio result for $\pi^0 \to e^+e^-$

Rune Niclasen

KTeV phone meeting

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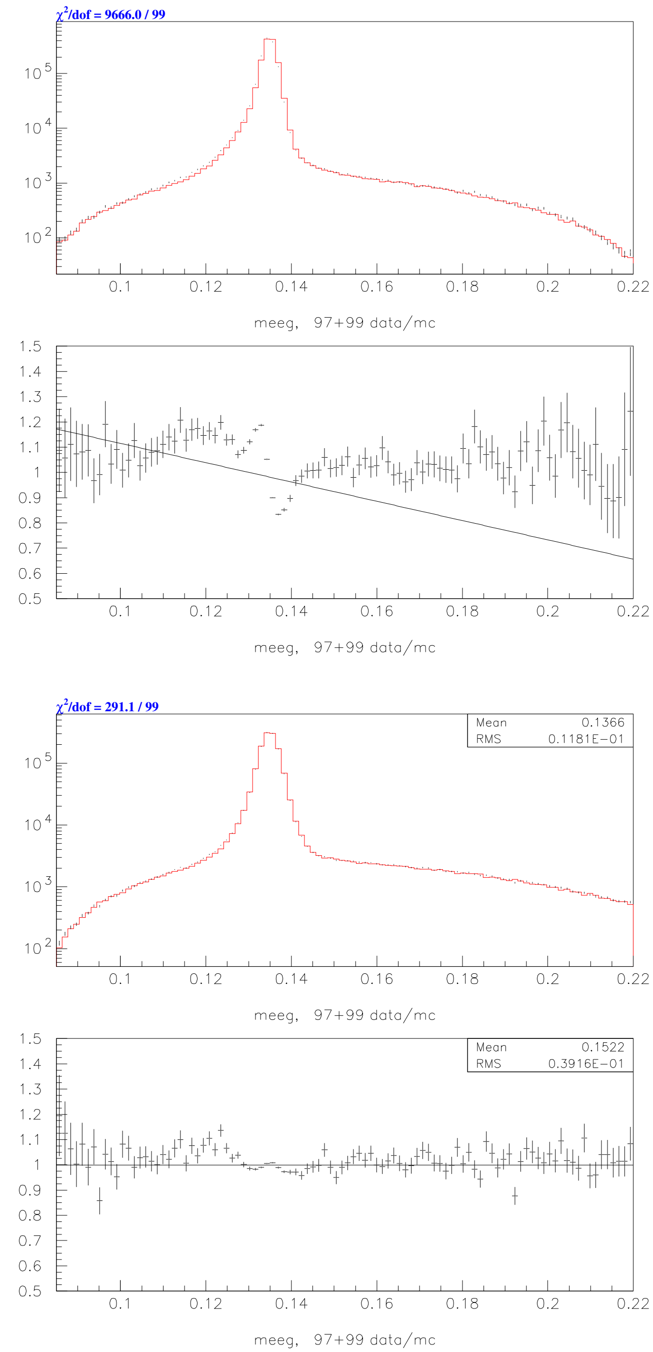
Outline

- Systematic studies
- Branching ratio result

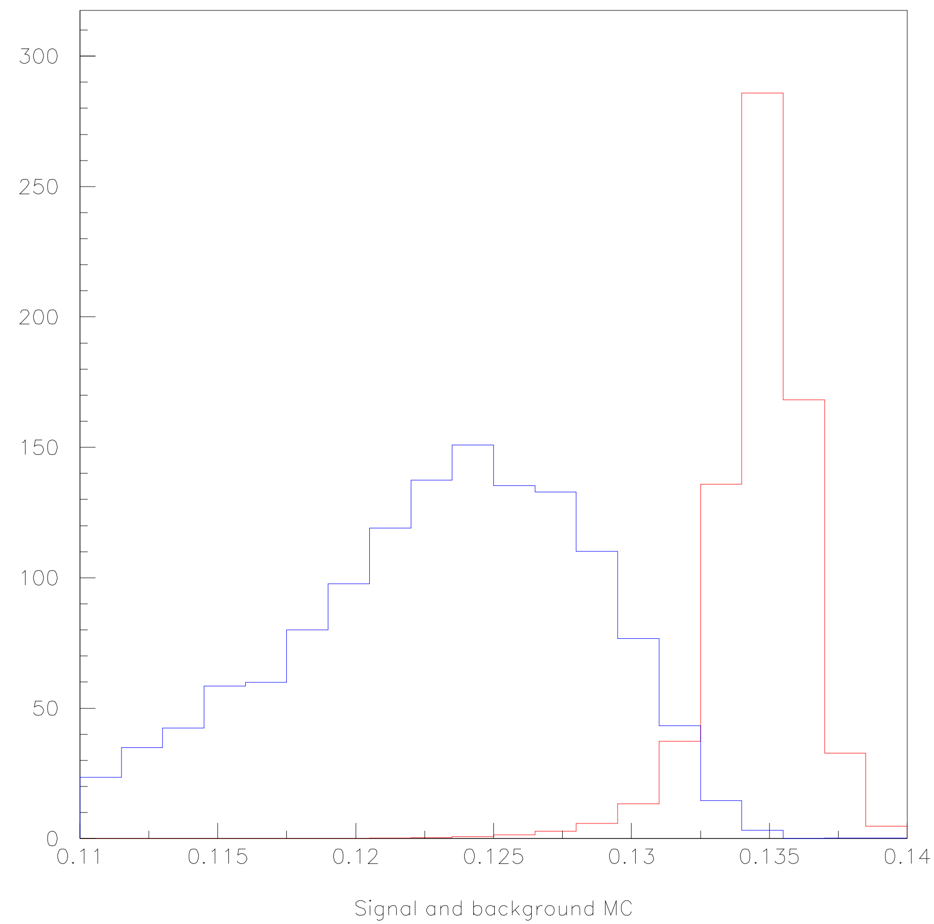
$e^+e^-\gamma$-mass peak shift

- Using the neutral vertex to get an averaged vertex for the kinematics makes the resolution better but has the unfortunate effect of shifting the ee-mass in data by 0.2 MeV and not in MC.
- To minimize the bias from the data being shifted low by 0.2 MeV in the data the cut on m_{ee} in the signal is shifted down by 0.2 MeV only in data.
- The signal region in data is 0.1314 MeV $< m_{ee} < 0.1382$ MeV and the signal region in MC is 0.1316 MeV $< m_{ee} < 0.1384$ MeV.



$e^+e^-\gamma$-mass peak shift

- Fixing this bias by hand introduces an uncertainty in the definition of the signal region. Acceptance and the background estimate is affected.
- Varying the cut by ± 0.2 MeV changes the signal acceptance at max 0.4% which can be neglected.
- The same variation of the cut changes the background estimate by 25% in 97 and 15% in 99 which translates into 1.4% and 0.8% uncertainty in the branching ratio for the two periods.
- Taking these numbers as systematic errors is very conservative, they even cover the case where there is no shift in either background or signal.

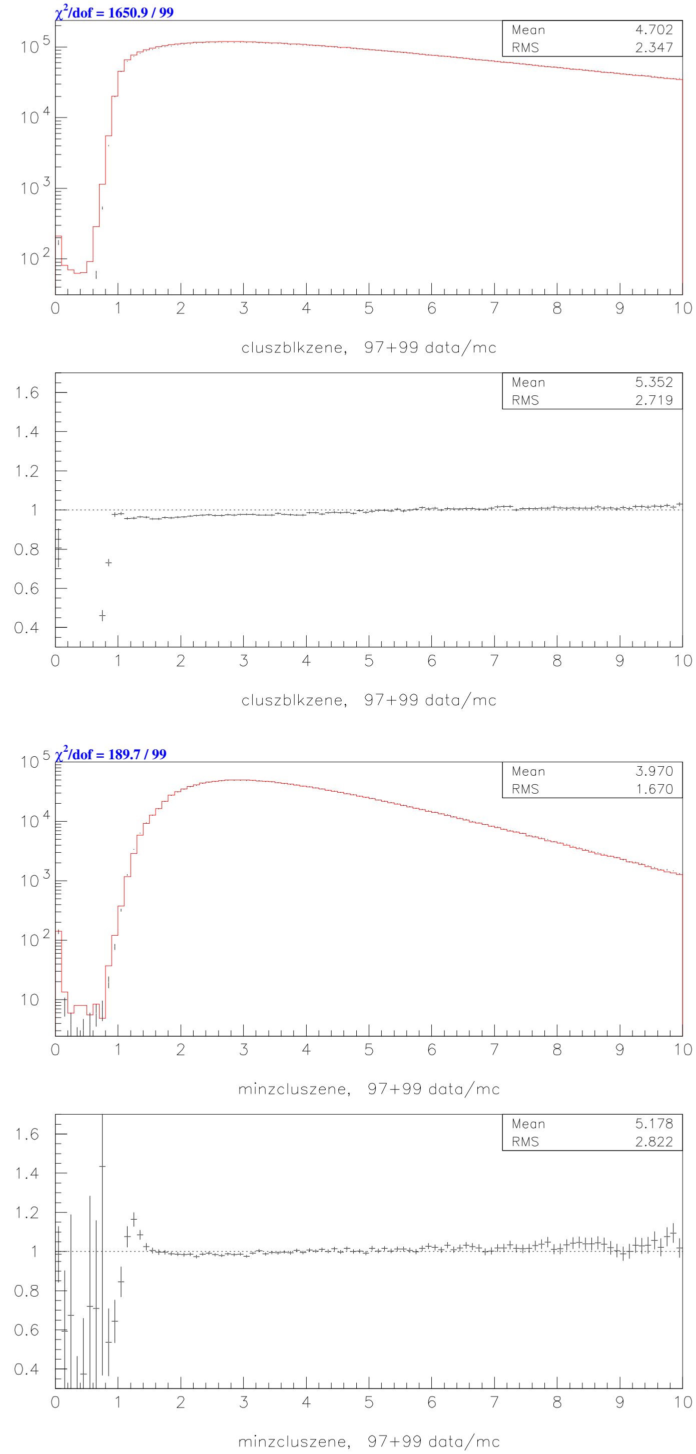


CsI energy resolution fudge

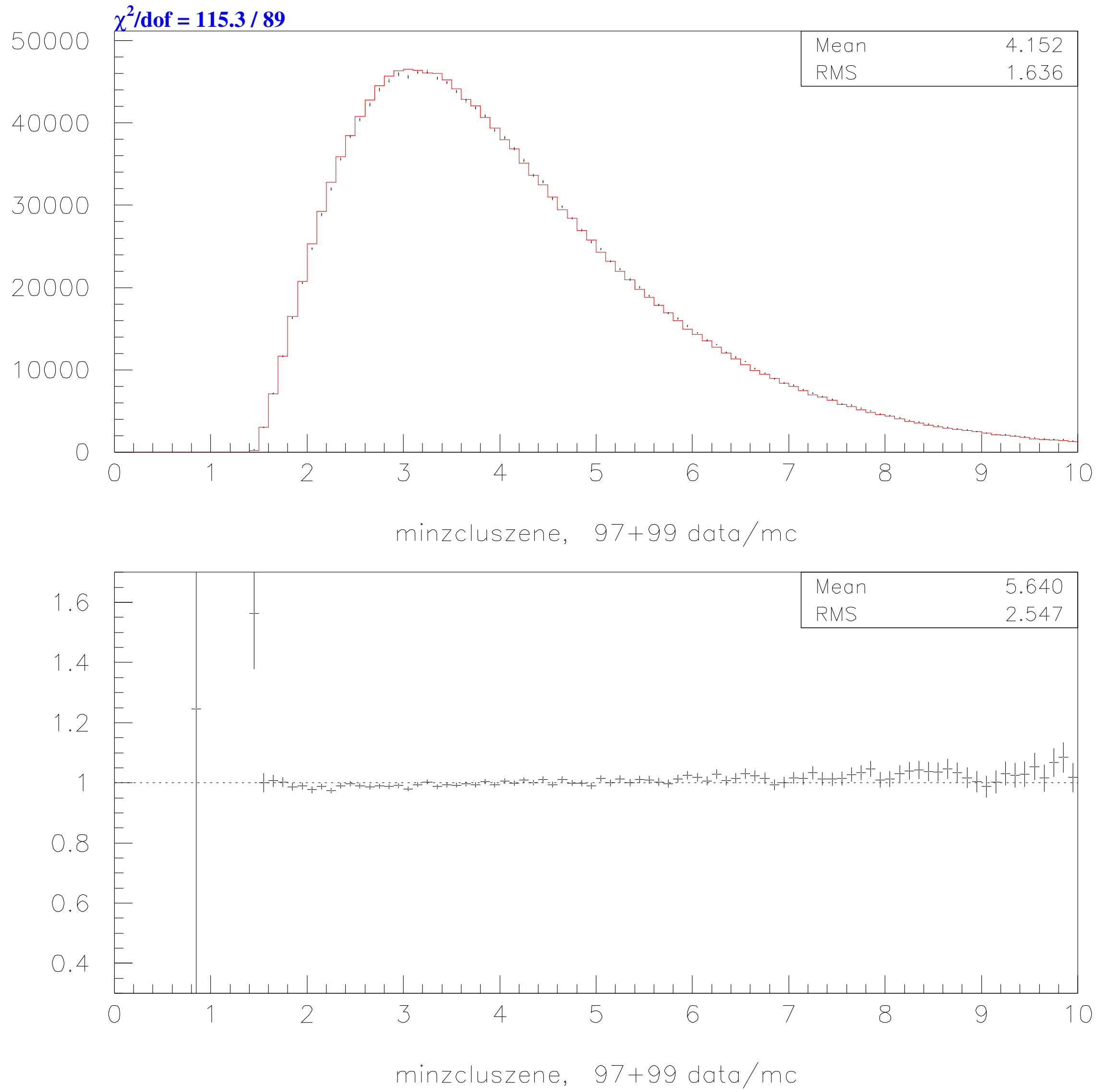
- The amount of fudged smearing to the MC is based on matching the neutral pairing χ^2 distribution between data and MC.
- Matching instead E/p or the $\gamma\gamma$-mass distribution suggests different amounts of smearing.
- The variation in the ratio of normalization acceptance to signal acceptance as the smearing is varied between the possible values should be taken as a systematic error.
- The variation is close 0.1% for all three run periods and will be neglected.

Photon efficiency in the calorimeter

- The modeling of the HCC threshold could cause a photon efficiency that could bias the result.
- To avoid depending on this model I make two cuts:
  - A cut on seed block energy of 1.2 GeV at the KTCLUS stage.
  - A minimum cluster cut of 1.75 GeV at the analysis stage.
- No remaining bias is expected since the minimum cluster energy distribution is now perfectly modeled

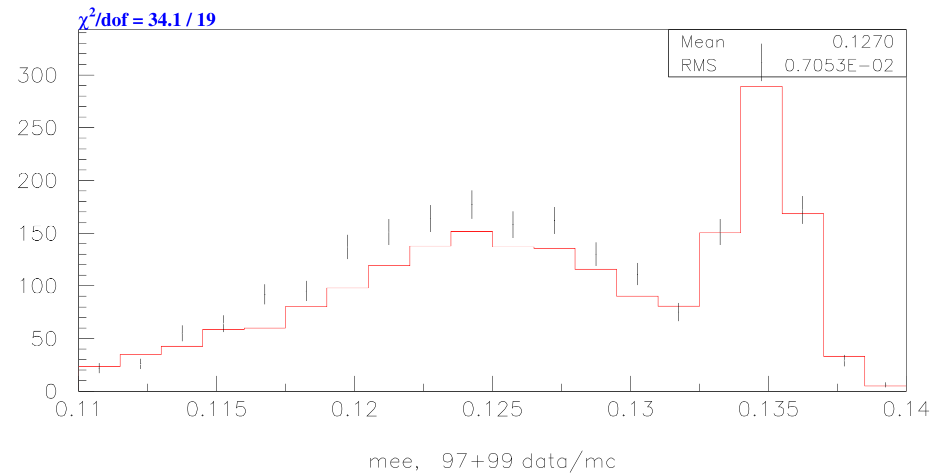


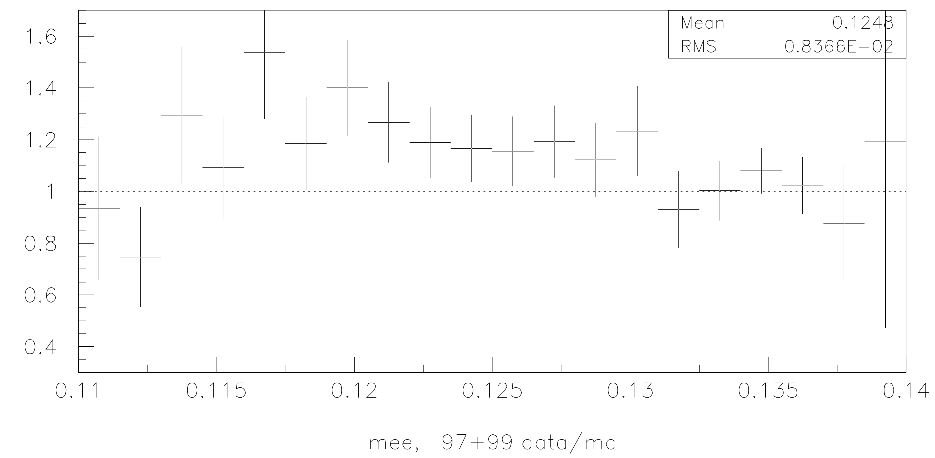
Photon efficiency in the calorimeter



Uncertainty on background estimate

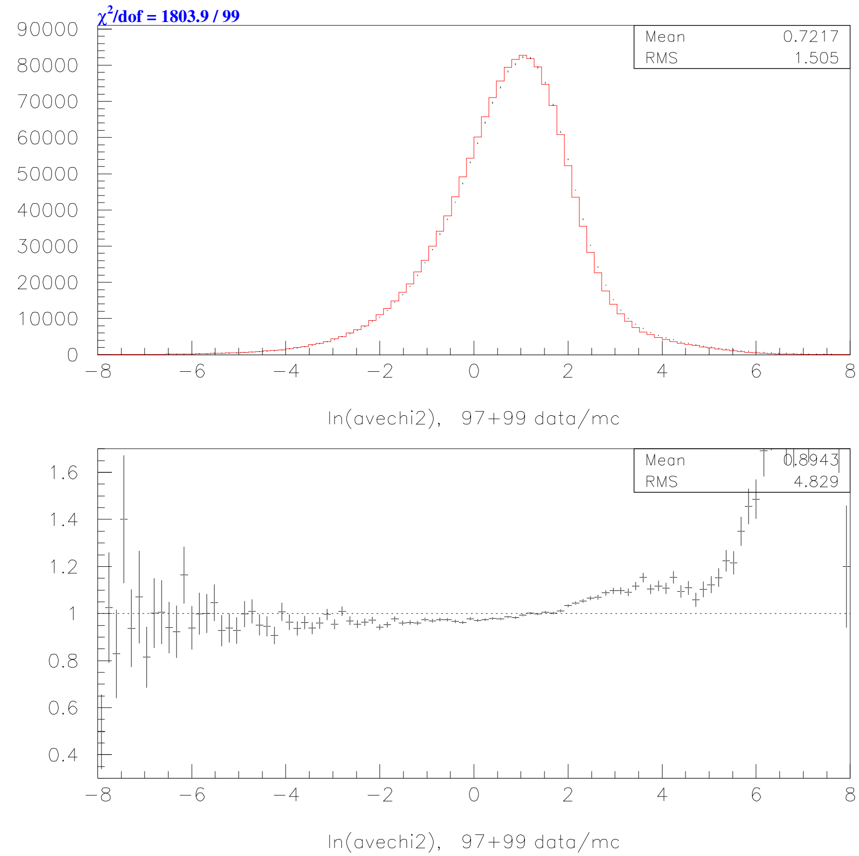
- There is a discrepancy in the background estimate of about 20%.
- Exactly what this background is and if it extends into the signal region is not known.
- A systematic error on the background of 20% is assigned.
- This translates into a 1.1% systematic on the branching ratio.
- Currently there is another 14% uncertainty on the background comming from MC statistics only. This gives another 0.8% uncertainty on the branching ratio.





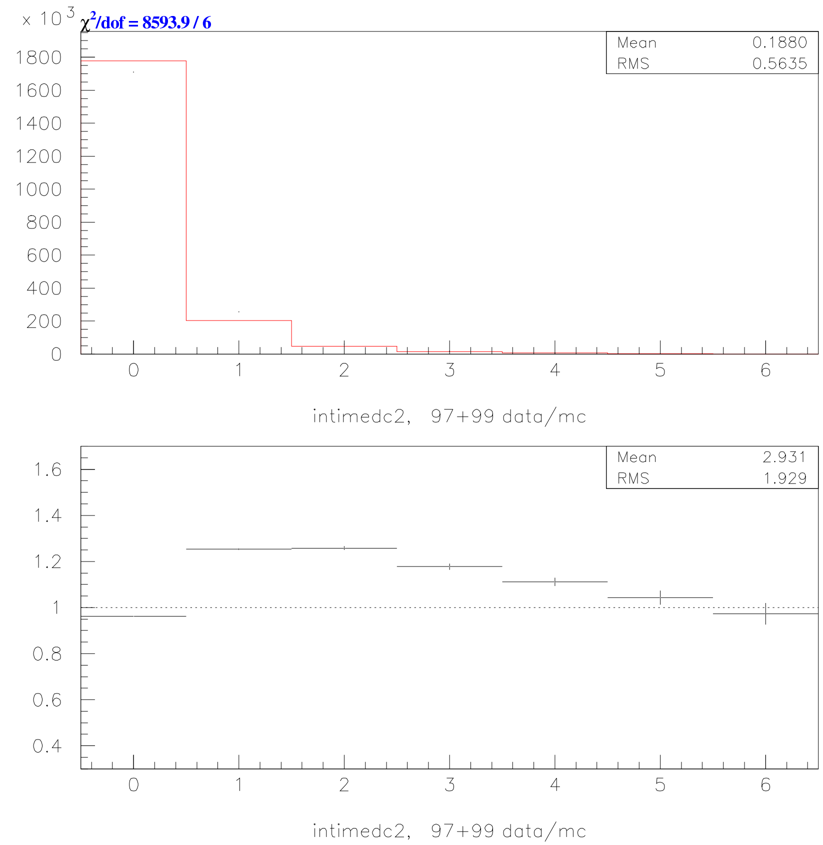
Averaged pairing χ^2

- The cut on the averaged pairing χ^2 could cause a bias if the disagreement in the tail that I'm cutting out is caused by some mispairing effect that I'm not simulating properly.
- Mispairings happen about 4% of the time in the normalization but less than 1% of the time for signal.
- Completely removing the cut changes the measured flux by 0.3% in 97 and 0.9% in 99 and is taken as a systematic error.

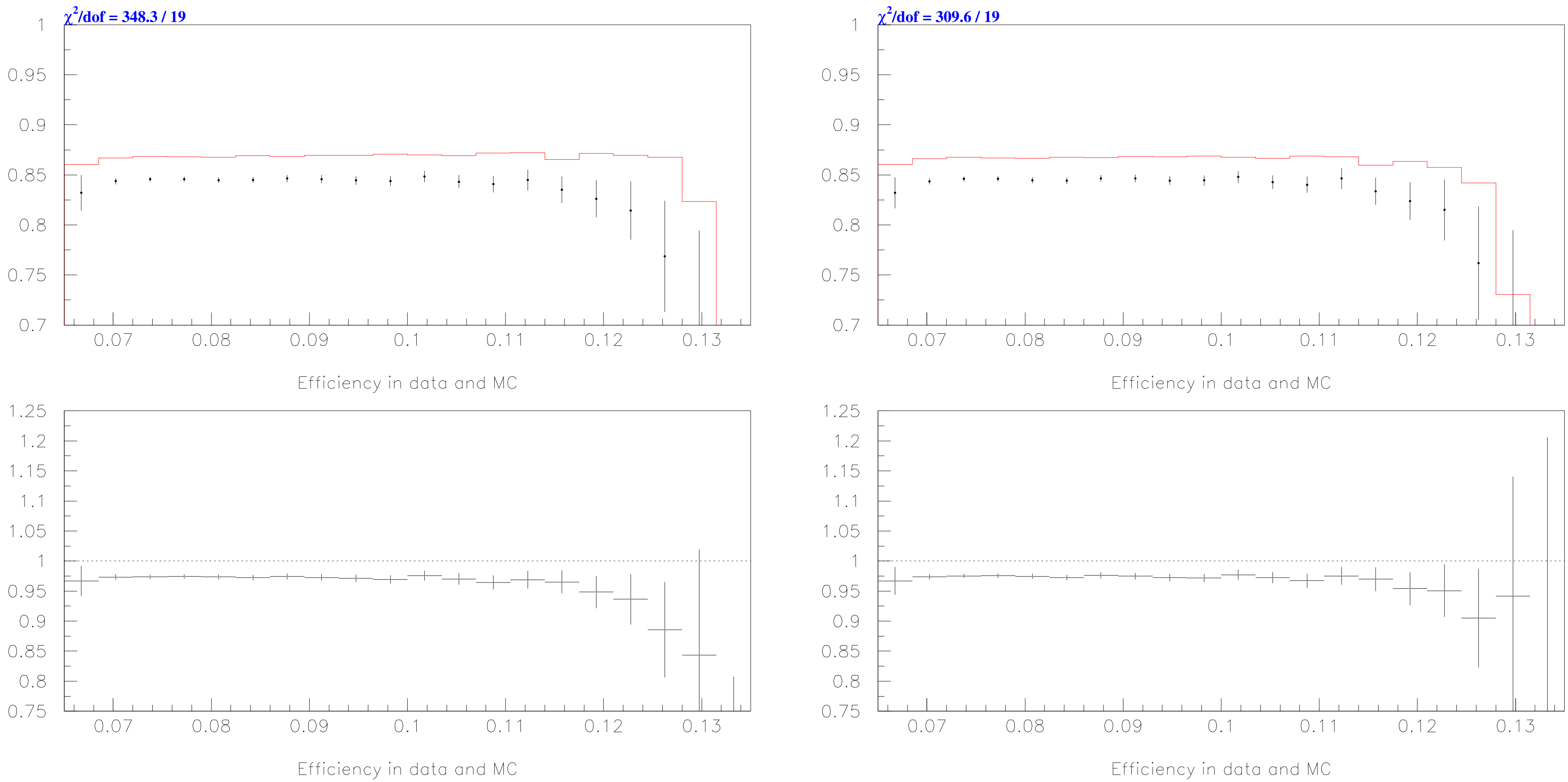


Extra activity in DC2 cut

- The is a clear discrepancy in the distributions of extra activity in DC2 between data and MC.
- The discrepancy shows no dependence on the cuts made and serves as an overall normalizing factor.
- Signal and normalization both have two tracks and the only difference between the two is the ee-mass.
- What is the efficiency of this cut in data and MC as a function of ee-mass?

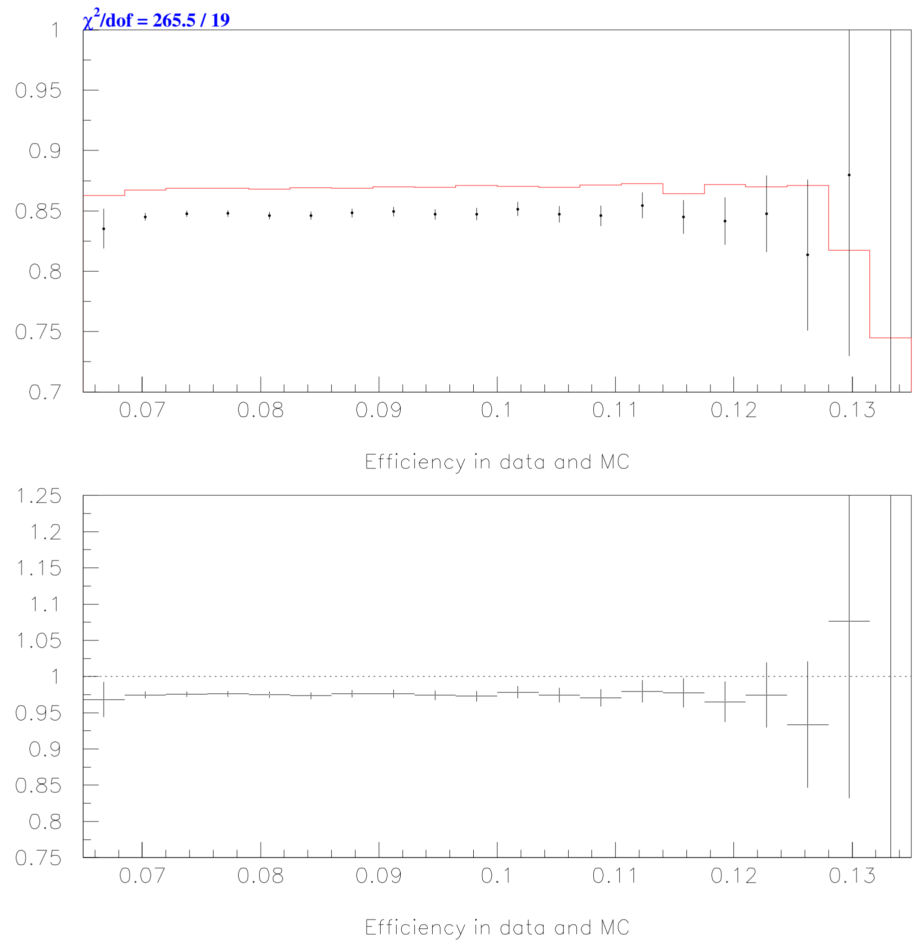


Extra activity in DC2 cut



Extra activity in DC2 cut

- Since I'm still not completely convinced I tighten the cut on the $ee\gamma$-mass to 130 MeV $< M_{ee\gamma} <$ 140 MeV.
- This gets rid of the last background on the high tail of the distribution and there is no longer any evidence that the cut will bias the result.



Other systematic errors

- The crunch cut on the ee-mass at 70 MeV is not done in MC exactly like it was done in data. This can affect the precision of the measured flux. Cutting tighter (75 MeV) changes the flux by 0.2% and will neglected.
- Like the averaged χ^2 the P$_T^2$ distribution has a tail that is not simulated well. The estimated systematic error is 0.4%.
- External systematics from the π^0 Dalitz branching ratio and form factor will enter and dominate the systematic errors
- Interference with the Dalitz decay. Bergström derives an upper bound on the interference as a function of m_{ee}. In the high mass region where I'm interested this contribution is totally negligible (0.001%).

Systematic error summary

Description	97	99
$ee\gamma/ee$-mass shift	1.4%	0.8%
Background estimate	1.4%	1.4%
Background MC statistics	0.8%	0.8%
Pairing χ^2 cut	0.3%	0.9%
P_T^2 cut	0.4%	0.4%
Resolution fudge	0.1%	0.1%
Quadrature sum	2.2%	2.1%

The branching ratio

- The measured quantity is the ratio:

$$\frac{\mathrm{Br}(\pi^0 \to e^+e^-, \quad x > 0.95)}{\mathrm{Br}(\pi^0 \to e^+e^-\gamma, \quad x > 0.2319)} = \frac{(N_{\text{obs,s}} - N_{\text{bkg}})/A_{\text{s}}}{N_{\text{obs,n}}/A_{\text{n}}}$$

	Winter	Summer	99
$N_{\text{obs,s}}$	170	117	427
N_{bkg}	10.2	6.8	22.9
A_{s}	$2.643 \pm 0.003\%$	$2.613 \pm 0.004\%$	$2.791 \pm 0.004\%$
$N_{\text{obs,n}}$	392197	272446	954918
A_{n}	$1.055 \pm 0.001\%$	$1.052 \pm 0.001\%$	$1.186 \pm 0.0008\%$
Br/Br	0.0001626	0.0001628	0.0001798

The branching ratio

- The absolute branching ratio can be extracted from

$$\text{Br}(\pi^0 \to e^+e^-,\ x > 0.95) = \frac{\text{Br}(\pi^0 \to e^+e^-,\ x > 0.95)}{\text{Br}(\pi^0 \to e^+e^-\gamma,\ x > 0.2319)} \times \text{Br}(\pi^0 \to e^+e^-\gamma) \cdot 3.181\%$$

- I combine the summer and winter periods immediately weighted by the measured flux. The 99 period has a significantly different acceptance so I keep it separate for now.

- Br(97) = $(6.20 \pm 0.39(\text{stat}) \pm 0.13(\text{sys}) \pm 0.17(\text{ext. sys})) \times 10^{-8}$
  Br(99) = $(6.85 \pm 0.35(\text{stat}) \pm 0.14(\text{sys}) \pm 0.18(\text{ext. sys})) \times 10^{-8}$

- The old KTeV result from 97 data only:
  $\text{Br}_{\text{old}}(97) = (6.09 \pm 0.40(\text{stat}) \pm 0.24(\text{sys})) \times 10^{-8}$

The branching ratio

- I'll combine the results by minimizing the χ^2 :

$$\chi^2 = \frac{(\mathrm{Br}(97) - \bar{\mathrm{Br}})^2}{\sigma^2(97)} + \frac{(\mathrm{Br}(99) - \bar{\mathrm{Br}})^2}{\sigma^2(99)}$$

  The errors are from statistics only.

- I get :

$$\bar{\mathrm{Br}}(\pi^0 \to e^+e^-,\ x > 0.95)\ =\ (6.56 \pm 0.26(\mathrm{stat}) \pm 0.14(\mathrm{sys}) \pm 0.18(\mathrm{ext.\ sys})) \times 10^{-8}$$

- The errors are combined with weights just like the branching ratios.
- The minimized χ^2 is 1.54 (1 degree of freedom). A χ^2 distribution tells me that a difference like this or worse will happen 21.4% of the time.
- Equivalently the significance of the difference between the 97 and the the 99 result is 1.24σ.

Flux measurements

- The KTeV flux of course can be extracted from the normalization analysis:

Winter	:	1.578×10^{11}
Summer	:	1.099×10^{11}
99	:	3.418×10^{11}

Bad spill mask, 1

Bit	Description	Win	Sum	99
1	Trigger	1	1	1
2	DPMT pedestal exponent > 0	1	1	1
3	Bad DPMT capacitor	1	0	0
4	Blown QIE comparator	1	1	1
5	Misc. dead DPMT	1	1	1
6	DPMT pedestal drift	0	0	0
7	DPMT gain drift	1	1	1
8	Broken DPMT dynode	1	1	1
9	CsI pipeline problems	1	1	1
10	Global CsI problems	1	1	1
11	E-total trigger problems	1	1	1
12	FERA ADC	1	1	1
13	Drift chambers	1	1	1
14	Photon veto	1	1	1
15	Trigger hodoscope	1	1	1
16	Muon veto/counter	1(*)	0	0

Bad spill mask, 2

Bit	Description	Win	Sum	99
17	HCC trigger	1(**)	1	1
18	Banana trigger	1	1	1
19	TRD trigger	0	0	0
20	Hyperon trigger	0	0	0
21	DAQ/L3 trigger	1	1	1
22	non-799 run	1	1	1
23	Short run	1	1	1
24	Non- standard TRD voltage	0	0	0
25	1 dead TRD plane	0	0	0
26	> 1 dead TRD plane	0	0	0
27	TRD voltage sag	0	0	0
28	Severe TRD problems	0	0	0
29	Beam problems	1	1	1
30	unused	0	0	0
31	unused	0	0	0
32	Miscellaneous	0	0	0